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PRELIMINARY STATISTICS ON THE ECCENTRICITIES OF COMET ORBITS.[1]

By A. O. LEUSCHNER.

Various investigations of the eccentricities of the orbits of comets have led to the conclusion that the majority of such orbits are parabolic. In fact, about three fourths of all comet orbits have been found consistent with an eccentricity equal to unity. This is the main reason why it is generally accepted that a comet orbit is parabolic, unless it can be shown to be otherwise.

An accurate knowledge of the eccentricities of comet orbits is of importance in determining the origin of comets. It is, therefore, advisable to study the eccentricities from as many points of view as possible. Two methods of classifying the eccentricities have occurred to me which do not seem to have entered into the analysis hitherto. Both are related to the accuracy of the observational material from which the orbits are derived. One is to classify the eccentricities on the basis of the general accuracy of the observations, the other on the basis of the observed heliocentric arc.

Marked progress has been made during the last century in the methods of observation and in the construction of telescopes, so that observations have become more and more reliable, and the number of days during which comets of the same brightness may be followed has constantly increased.

Ever since the first computation of a comet orbit was made, it has been customary to derive a parabola as a first approximation to the orbit, and to attempt a more general solution only if the deviations of the observed positions from the places computed from the most probable parabola were in excess of the probable errors of observation. This custom has become so thoroughly fixed in astronomy that even now it would be considered absolutely unwarranted to suspect a comet of moving in an ellipse if by a little stretching of the probable limits of observational error a parabola could be found to represent the observed positions.

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[1] Abstract of address of the retiring President of the Society, presented at the annual meeting, March 30, 1907.

A prejudice has always existed, and exists now, in favor of the parabola. This prejudice is not entirely due to statistical investigations of the orbits of past comets. A further excuse for the same may be found in the fact that the first geometrical and analytical methods for solving a comet orbit were parabolic. The solution of an elliptic orbit was originally possible only in cases like HALLEY'S comet, where more than one appearance had been observed, so that one of the unknowns, the period, became known.

GAUSS'S general solution had its first application on the asteroid *Ceres,* at the dawn of the nineteenth century, and it was not until some time later that general methods were also applied to comets.

It is a well-recognized fact that when the observed arc is short and the probable error of observation on a comet is large, the solution of the orbit will be uncertain, or, in other words, in such cases a large number of different orbits will be found to satisfy the observations. The "Short Method" which has been used extensively in the Berkeley Astronomical Department during the last three years is well suited for estimating the limiting values of the elements. The range of possible periods and eccentricities is far greater than has perhaps been supposed hitherto. A cursory examination of many definitive orbits based on normal places formed from long series of observations shows that in many cases a long-period ellipse will often answer as well as a parabola. The ellipse is then generally dismissed with the statement that there is no reason to suspect a deviation from the parabola. It would be just as consistent to conclude that there is no reason to suspect that the comet moves exactly in a parabola. In accordance with existing belief regarding the eccentricities of comet orbits, Dr. KREUTZ in his biennial reports to the Astronomische Gesellschaft adopts the parabola whenever it is found sufficient.

Before proceeding to an examination of the published lists of elements it is therefore well to emphasize that possibly in no case where an ellipse or hyperbola alone is given can the observations be represented by a parabola, but when a parabola is given the observations may frequently be consistent with an ellipse and sometimes with a hyperbola.

If, in spite of this fact, it can be demonstrated that by far the majority of well-determined orbits is elliptic, then the time has come when astronomers should abandon their prejudice for the parabola, by investigating and stating the complete range of possible solutions in each case.

OLBER'S, GALLE'S, and WINLOCK'S lists were not available when a preliminary examination of the eccentricities was undertaken. The excellent list, however, contained in E. WEISS'S edition of "Littrow, Wunder des Himmels," is well suited for the purpose of the preliminary investigation, especially because it gives the duration of visibility in days. This list runs to 1885. The results of the preliminary examination were, however, roughly revised just before publication on the basis of GALLE'S and WINLOCK'S lists and KREUTZ'S biennial reports to the Astronomische Gesellschaft to 1904, which latter are contained in the *Vierteljahrsschrift.* Comets discovered between 1885 and 1895 were added to WEISS'S list only when the duration of visibility was included in the data at hand. Periodic comets are, of course, counted only for their first apparition.

For the purpose of classifying the orbits on the basis of the general accuracy of the observational material, or more nearly of the observed positions, the percentage of parabolic orbits was ascertained for each of three groups, in the order of time as given in Table I.

TABLE I.

Dates.	$e = 1$
–1755	99 per cent
1756–1845	74 per cent
1846–1895	54 per cent

It is safe to assume that there has been a progressive and pronounced advance in the accuracy of observation in these three periods of time. Hyperbolic orbits were not included in the totals on which the percentages of Tables I and II are based. From the more accurate observations of the fifty years from 1846 to 1895 we may therefore conclude that it is no more probable that a comet is parabolic than that it is not.

In Table II the eccentricities have been grouped on the basis of the duration of visibility in days. The percentage of parabolas is given for each group. The comets discovered before 1756 have been excluded in the totals from which these percentages were derived, as their orbits can throw little light on the question under consideration.

TABLE II.

Duration of Visibility.	e = 1
1– 99 days	68 per cent
100–239 days	55 per cent
240–511 days	13 per cent

These figures are certainly striking. They show that the longer a comet is under observation the more probable it becomes that its orbit cannot be satisfied by a parabola.

This result is in entire accordance with the opinion held by some astronomers that few, if any, orbits are strictly parabolic. In the last group only eight comets were available, which are all given as elliptic by WEISS, and for one of these KREUTZ's later reports give a parabola, which has been adopted, the same as every orbit has been considered parabolic in these tables for which the observations could be satisfied by a parabola. It is therefore extremely doubtful whether a parabola is definitely established for any comet having remained visible 240 days or more. It would have been better if Table II could have been based on the length of the observed heliocentric arcs, but these are not immediately available, and in a first approximation for a large number of comets the average of the number of days of visibility may be taken to correspond to the average heliocentric arc.

Percentages have also been derived for various ranges of eccentricity. These, however, will not be published until the final investigation has been concluded.

The average eccentricity of periodic orbits is very high. In applying the short method it has been found that whenever a short arc yielded a considerable range of periodic solutions, a longer arc would yield solutions for the eccentricity nearer the upper than the lower previous limits. The explanation of the high eccentricities lies in the nature of things. Long-period comets cannot come within the range of visibility from the Earth unless their orbits are highly eccentric. The others must remain invisible, until the power of our telescopes is still further increased.

From the average brightness of comets at unit geocentric distance the maximum perihelion distance at which a comet may be seen in opposition from the Earth with the more powerful instruments may be derived. The values of the eccentricity corresponding to this maximum for a given value of the semi-major axis or period will then be the minimum eccentricity which the orbit of a comet of average brightness and of given period must have in order to be visible from the Earth, under the most favorable circumstances.

This question will be studied in connection with a proposed further study of comet orbits. The theory that, in general, comets are permanent members of our solar system seems to have been greatly strengthened by the foregoing preliminary statistics. It will be remembered that until KEELER began photographing nebulæ with the Crossley reflector the spiral was considered the exceptional form of a nebula. The percentage of double stars is increasing so rapidly that their discovery either directly, or spectroscopically, or photometrically, or otherwise, is no longer a cause for surprise. It seems eminently probable that with further investigation of cometary orbits the parabola will be found to be the exception.

BERKELEY ASTRONOMICAL DEPARTMENT, March 30, 1907.

THE SOLAR CORONA.[1]

BY W. W. CAMPBELL.

Of all the wonders of this and other worlds that it has been my good fortune to see, a total solar eclipse is by far the most impressive, and the Sun's corona is its central and most beautiful feature. The corona appears to have attracted the attention of intelligent observers who dwelt within the shadow-paths, in all ages of our civilization. PLUTARCH has left an excellent description of its appearance, and occasional later

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[1] Lecture delivered before the Astronomical Society of the Pacific on January 28, 1907. The lantern slide illustrations are necessarily omitted.